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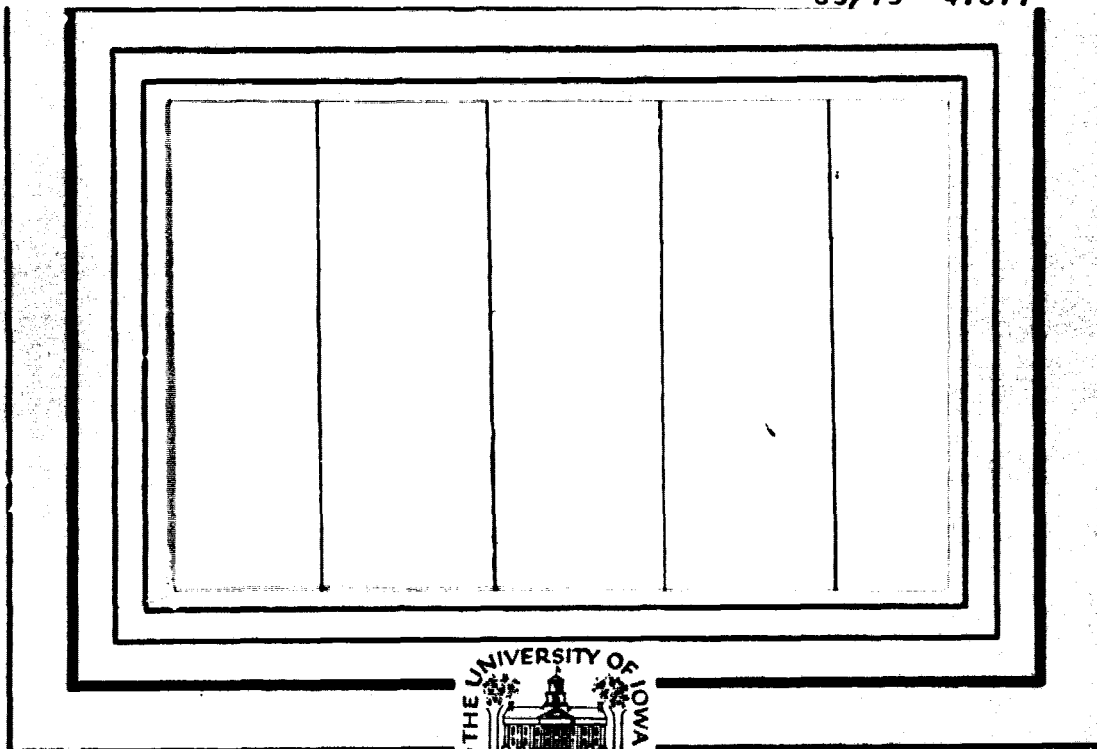
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REPLY IN RESPONSE TO
COMMENT BY E. W. HONES*

by

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*Comment authored by E. W. Hones concerning the paper "On hot tenuous plasmas, fireballs, and boundary layers in the earth's magnetotail" by L. A. Frank, K. L. Ackerson and R. P. Lepping, J. Geophys. Res., 81, 5859, 1976.

Hones [1977] points out the marked disagreement between the plasma flow measurements reported by Frank et al. [1976] and those obtained with the LASL plasma analyzer. He suggests (1) that solar ultraviolet background rates may have been incorrectly accounted for in the computation of proton bulk flows in the magnetotail as reported by Frank et al. [1976] and (2) that bulk flows with substantial speeds, $\gtrsim 50 \text{ km}(\text{sec})^{-1}$, are seldom encountered in the plasma sheet at geocentric radial distances $\sim 35 R_E$. We demonstrate here that such ultraviolet responses were carefully considered by Frank et al. [1976] and maintain our conclusion that bulk flows $\gtrsim 50 \text{ km}(\text{sec})^{-1}$ frequently occur in the plasma sheet at these radial distances. Further, a direct comparison of the capabilities of the LASL plasma analyzer employed by Hones and of the LEPDEA [Frank et al., 1976] indicates that there are rather severe restrictions on which plasmas in the plasma sheet can be properly measured to gain proton temperatures, number densities and flow velocities with the LASL plasma analyzer.

Observations of the proton velocity distribution function $n(V)$ near the direction of flow and 180° from this direction are shown in Figure 1 for the period 1700 to 1830 UT on April 18, 1974. Densities with the LEPDEA field-of-view centered at 350° (generally sunward) are shown as open circles; measurements at $\phi_{SE}^L = 170^\circ$ are indicated with closed circles. The densities at $\phi_{SE}^L = 350^\circ$ have been corrected for solar

ultraviolet responses by using instrument background rates during the period 1700 to 1800 UT on April 17, 1974 (the previous day) when no plasma was present at the satellite position. This background response is a slowly varying function of time and is determined for each crossing of the magnetotail with IMP-8. One standard deviation of the background responses is 9% of the averaged response. The standard deviations ($\pm 1 \sigma$) due to counting statistics for the LEPDEA are indicated in Figure 1 and following figures. The contributions of the solar ultraviolet fluxes to instrument responses were 54%, 34% and 58% at $V = 310, 910$ and $2090 \text{ km}(\text{sec})^{-1}$, respectively. In order to render the densities at $910 \text{ km}(\text{sec})^{-1}$ for $\theta_{SE}^L = 170^\circ$ and 350° equal by a subtraction of a corresponding background rate the error in the determination of these solar ultraviolet rates must have been by a factor of approximately 2. If such were the case the background responses would have exceeded the total instrument responses at the higher and lower portions of the velocity ranges shown in Figure 1. No background responses are present at $\theta_{SE}^L = 170^\circ$ (solid circles). A Maxwellian with number density 0.5 cm^{-3} and $kT = 1.6 \text{ keV}$ and flowing with a speed of $70 \text{ km}(\text{sec})^{-1}$ has been fitted to the LEPDEA measurements in Figure 1 (dashed line). At $V \gtrsim 800 \text{ km}(\text{sec})^{-1}$ the velocity distribution has a high-velocity 'tail', a common feature of proton observations in the plasma sheet. The velocity distribution for $\theta_{SE}^L = 350^\circ$

has been mirror-reflected about $V = 70 \text{ km}(\text{sec})^{-1}$ in Figure 1 in order to assess graphically the bulk flow speed, $70(+20) \text{ km}(\text{sec})^{-1}$. The corresponding routinely computed value is $83(+5) \text{ km}(\text{sec})^{-1}$. This proton bulk flow is directed tailward and agrees in magnitude and direction with those flows previously reported by Frank et al. [1976].

We also show in Figure 1 the results reported by Hones [1977] that indicate no bulk flow for the same period as deduced from the responses of the LASL plasma analyzer. The determination of the velocity distributions at high velocity is limited by the energy range of the plasma analyzer and at low velocity by cosmic ray background rates.

The average isotropy of the proton velocity distributions during 1700 to 1830 UT on April 18 as presented by Hones [1977] is similarly not supported by simultaneous observations with the LEPEDEA. These densities as functions of the LEPEDEA viewing directions (nearly in a plane parallel to that of the ecliptic) are summarized in Figure 2. The observations with the LEPEDEA demonstrate that the angular distributions have two minima at $\sim 70^\circ$ and 250° , and two maxima at $\sim 160^\circ$ and 340° . In other words, the distribution is 'cigar-shaped'. The directions of the geomagnetic field during this period were generally in directions corresponding to either of the two maxima of densities

[cf. Frank et al., 1976]. The difference in densities between the two maxima is indicative of tailward flow. The percentage fluctuations in densities between the lesser maximum and the minima, and that between the two maxima, are similar and are about 30%. No background corrections were necessary except near the solar direction as mentioned previously.

Hones [1977] also reports that the responses of the LASL plasma analyzer are consistent with no discernible proton bulk flows during 0500 to 0600 UT on April 6, 1974. For this interval simultaneous measurements with the LEPEDEA yield an average flow velocity of $140 \text{ km}(\text{sec})^{-1}$ and generally directed tailward [cf. Frank et al., 1976]. Measurements of the velocity distribution of these protons with the LEPEDEA at $\phi_{SE}^L = 125^\circ$ are shown in Figure 3. The proton number density is 0.15 cm^{-3} and kT is 12.8 keV. The maximum proton energy that is accessible to the LASL plasma analyzer is 15.3 keV. Hence it appears inappropriate to employ the LASL plasma analyzer to determine number densities, bulk flows or temperatures for these hotter plasmas within the plasma sheet, since the determination of proton intensities is limited to the highest one or two energy channels of the LASL instrument.

Prolonged tailward and earthward plasma flows, for periods of an hour or more, were reported by Frank et al. [1976]

via observations of these plasmas with a LEPDEA on board IMP-8 at geocentric radial distances ~ 30 to $35 R_E$. A further example of prolonged tailward flows, not unusual at these radial distances, is offered in Figure 4. These measurements were gained with a LEPDEA on IMP-7 during 1420 to 1600 UT on October 31, 1975 and required no background corrections for solar ultraviolet radiation [cf. Frank et al., 1977]. Background rates due to penetrating energetic particles are negligible. The proton densities, temperatures and flow velocities at this position within the plasma sheet were similar to those reported above for April 18, 1974 with IMP-8. With the exception of a brief interval of earthward flow centered at 1510 UT, the proton bulk flow is directed tailward in Figure 4. The tailward component for the averaged flow for 1420 to 1600 UT is $90(+3) \text{ km}(\text{sec})^{-1}$. At the radial distances corresponding to the IMP-8 orbit ($X_{sm} \sim -25$ to $-30 R_E$), Hones [1977] also shows in his Figure 3 the presence of flows exceeding $50 \text{ km}(\text{sec})^{-1}$ for 20 to 25% of his measurements during even carefully selected periods of geomagnetic quiescence. The notable decrease of flow speeds with decreasing distance from earth as evident in his Figure 3 has already been mentioned by Frank and Ackerson [1976].

It is important to realize that the two instruments concerned were designed for measurements in two distinct plasma regimes: the LEPDEA for hot tenuous plasmas within

planetary magnetospheres, and the LASL detector for solar-wind plasma. While both instruments can provide useful information in both regimes, they enjoy certain advantages and capabilities in measuring the plasmas for which they were designed. Any attempt to interchange their respective roles is frequently liable to lead to difficult and marginal interpretations.

In the case of the measurement of proton bulk flows in the magnetospheric tail, interpretation is especially difficult because the flow speeds are usually substantially less than the proton thermal speeds. The signatures of these bulk flows are thus typically small departures from isotropy in the observed angular distributions of proton intensities. Often the determinations of flow speeds in the ecliptic plane from the two instruments are in agreement, but sometimes they appear to differ substantially. The two cases of disagreement discussed in this exchange occur on April 18 (relatively cool plasma) and April 6 (impressively hot plasma). In the latter case, the LEPDEA results led to a flow speed of $140(+40) \text{ km}(\text{sec})^{-1}$ based on a sampling of about 95% of the proton velocity distribution. The corresponding measurement by the LASL detector was $47(+104) \text{ km}(\text{sec})^{-1}$ based on a sampling of about 30-40% of the proton velocity distribution, i.e., within one standard deviation of the result gained with the LEPDEA. We do not consider these results as being necessarily disparate.

In the former case of a cool diffuse plasma on April 18 the LEPDEA observation of a tailward flow of $83(+25) \text{ km(sec)}^{-1}$ and the LASL measurement of a tailward flow of $10(+12) \text{ km(sec)}^{-1}$ are in clear disagreement, but the disagreement is not due to the lack of an adequate correction for solar ultraviolet response of the LEPDEA instrument. Such corrections have been made to the responses of the IMP-8 LEPDEA for the past three years, and their effectiveness has been verified by comparison of simultaneous measurements with the IMP-7 LEPDEA in the plasma sheet and with other plasma analyzers (hybrid LEPDEAs) on IMP-7 and IMP-8. These three latter instruments are not susceptible to solar ultraviolet radiation. On the other hand, the proton distribution on April 18 was such that the responses of the LASL instrument to proton intensities were greater than background rates for only about 15-20% of the proton velocity distribution. The corresponding percentage for the LEPDEA measurements was about 99%.

Rapid progress in understanding the dynamics and structure of the earth's magnetotail has occurred over the past year, and it is not unexpected that a number of interpretive differences will arise between research groups. This is merely a sign of a healthy and active area of research. However, we must be careful not to choose limited series of measurements for detailed analyses and conclude that they are typical of the magnetotail without completing comprehensive

surveys. The complexities of the magnetotail demand more than a cursory examination of a few examples, say, of substorms or boundary crossings. We fully expect that efforts to resolve disagreements of the kind described here will lead to important contributions to our expanding knowledge of the exciting phenomena in the earth's magnetotail.

Acknowledgments

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Figure Captions

- Figure 1.** Comparison of simultaneous observations of the proton velocity distributions with the LEPEDea and LASL plasma analyzers on board IMP-8 during 1700 to 1830 UT on April 18, 1974. IMP-8 was positioned within the plasma sheet in the earth's magnetotail.
- Figure 2.** Continuation of Figure 1 and showing the azimuthal dependences of $n(V)$ as detected with the LEPEDea.
- Figure 3.** The proton velocity distribution as measured with the LEPEDea on IMP-8 during 0500 to 0600 UT on April 6, 1974. The spacecraft was again located within the plasma sheet.
- Figure 4.** Measurements of dominant tailward flow of protons with the LEPEDea on IMP-7 during 1420 to 1600 UT, October 31, 1975. The proton number densities, temperatures and flow speeds are similar to those of Figure 1. No background corrections due to solar ultraviolet radiation or penetrating, energetic charged particles were required for the corresponding LEPEDea responses.

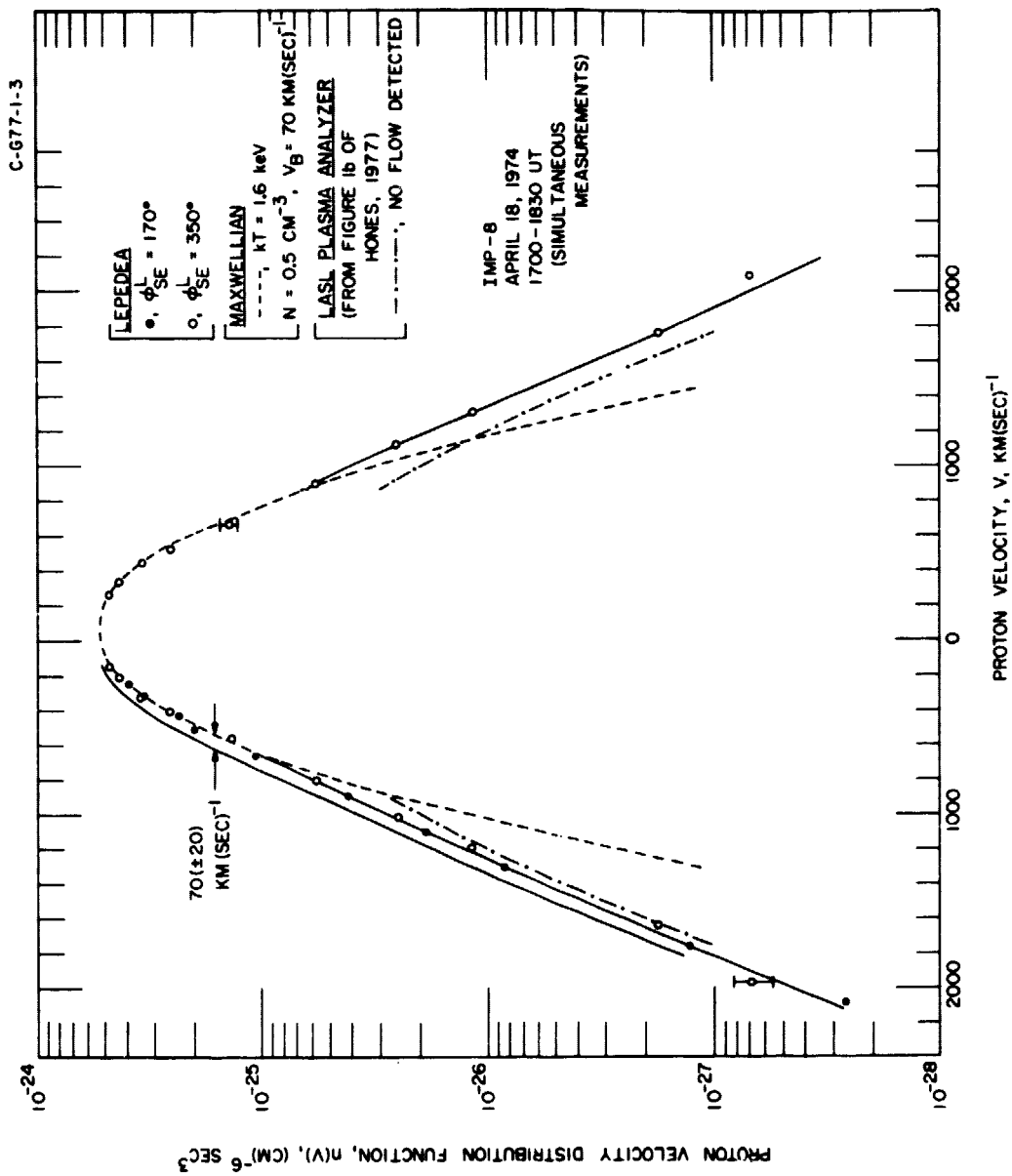


Figure 1.

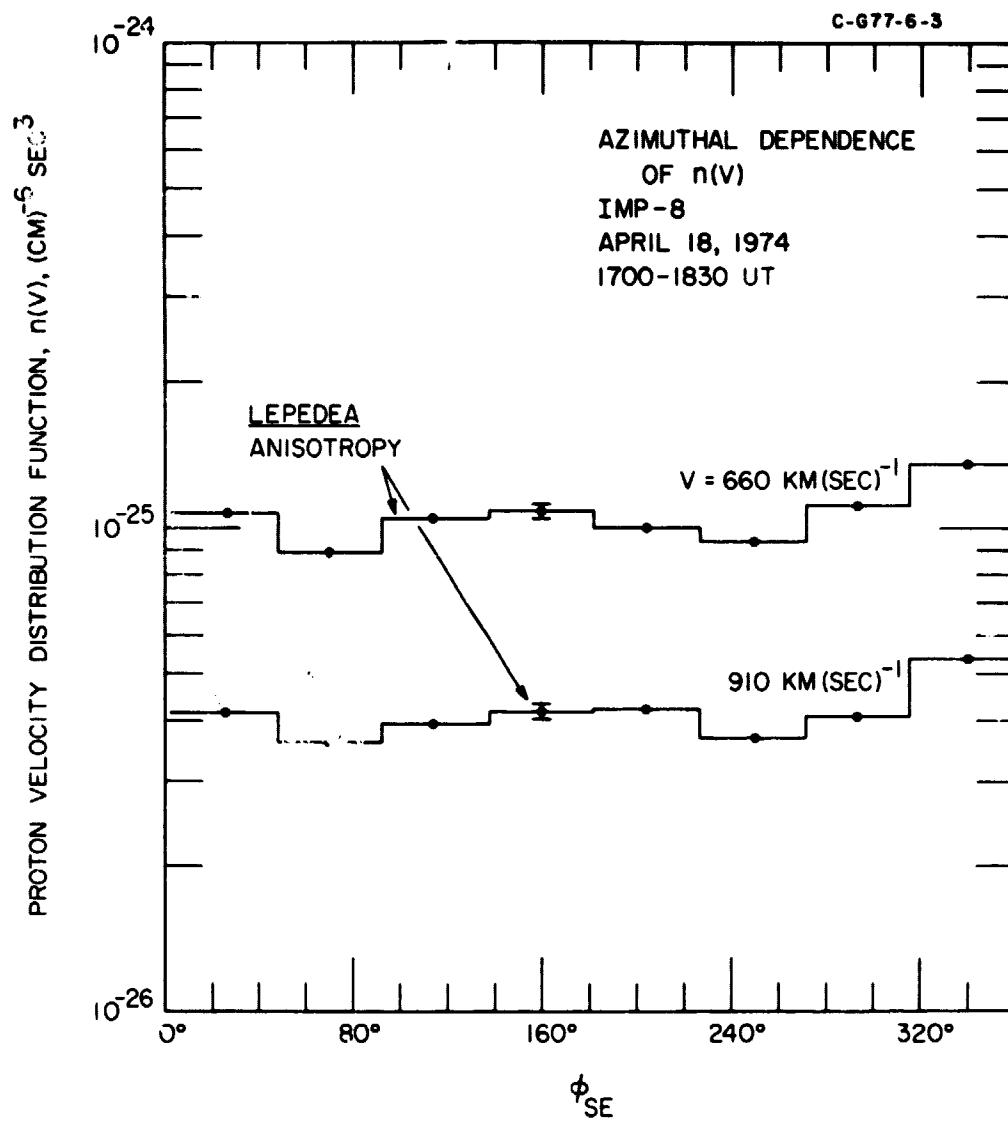


Figure 2.

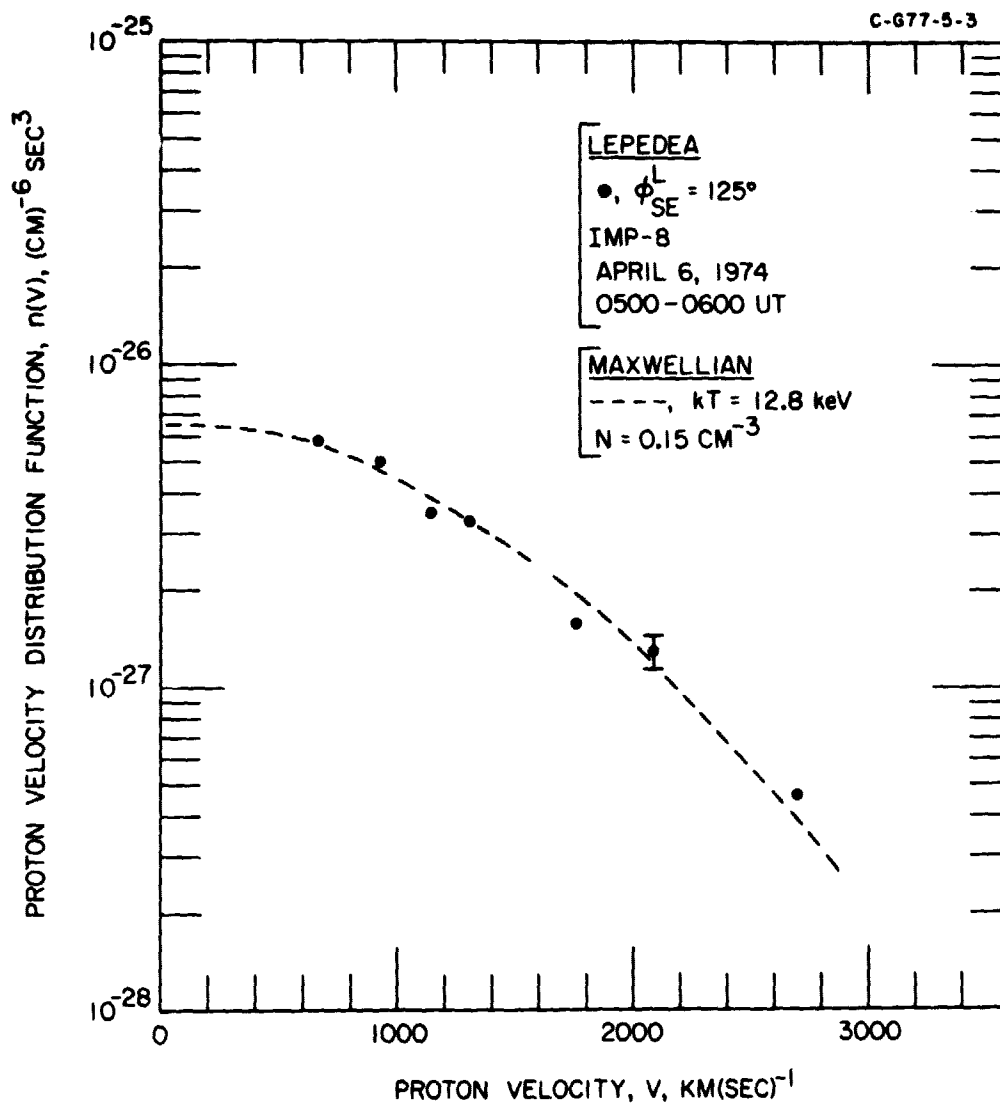


Figure 3.

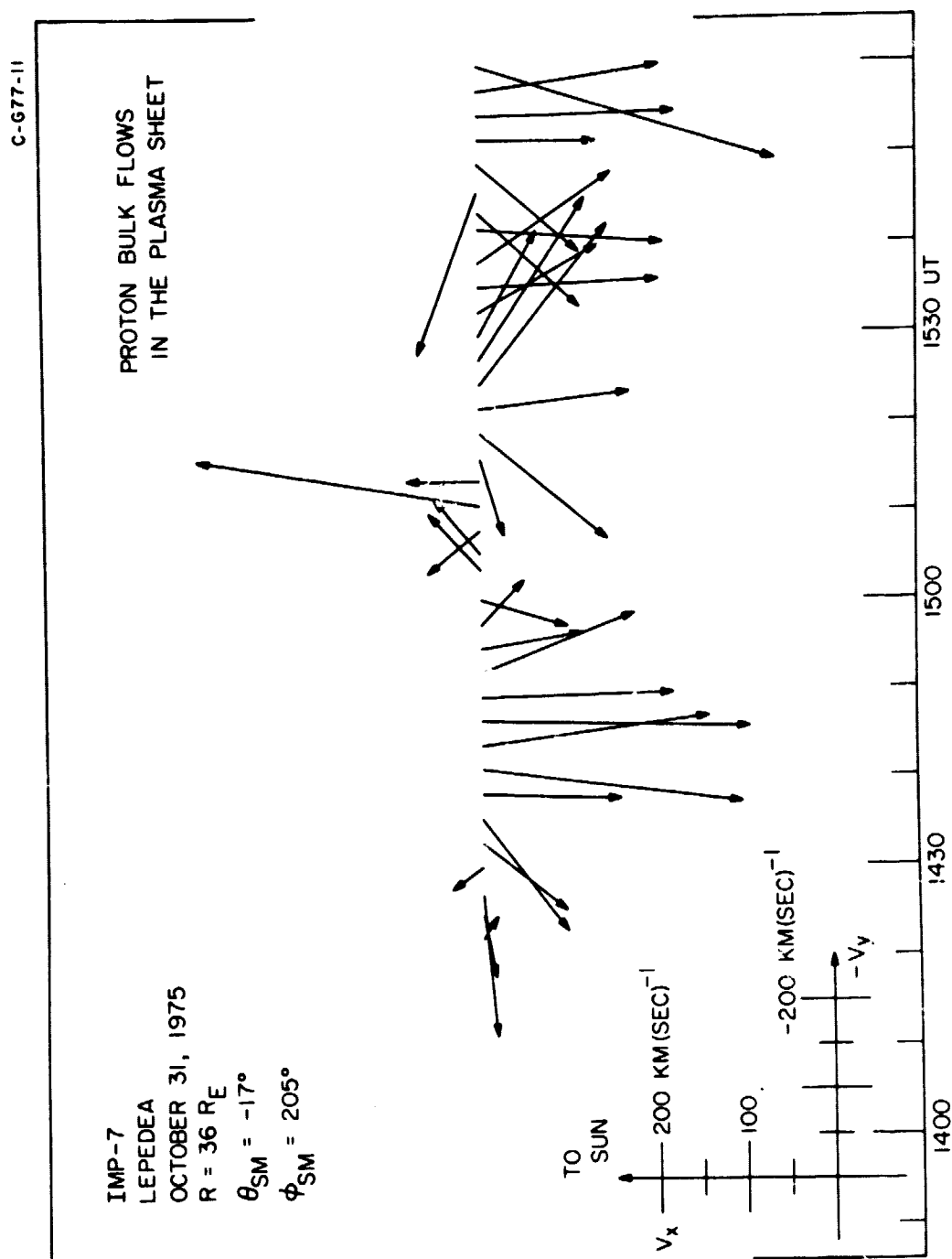


Figure 4.